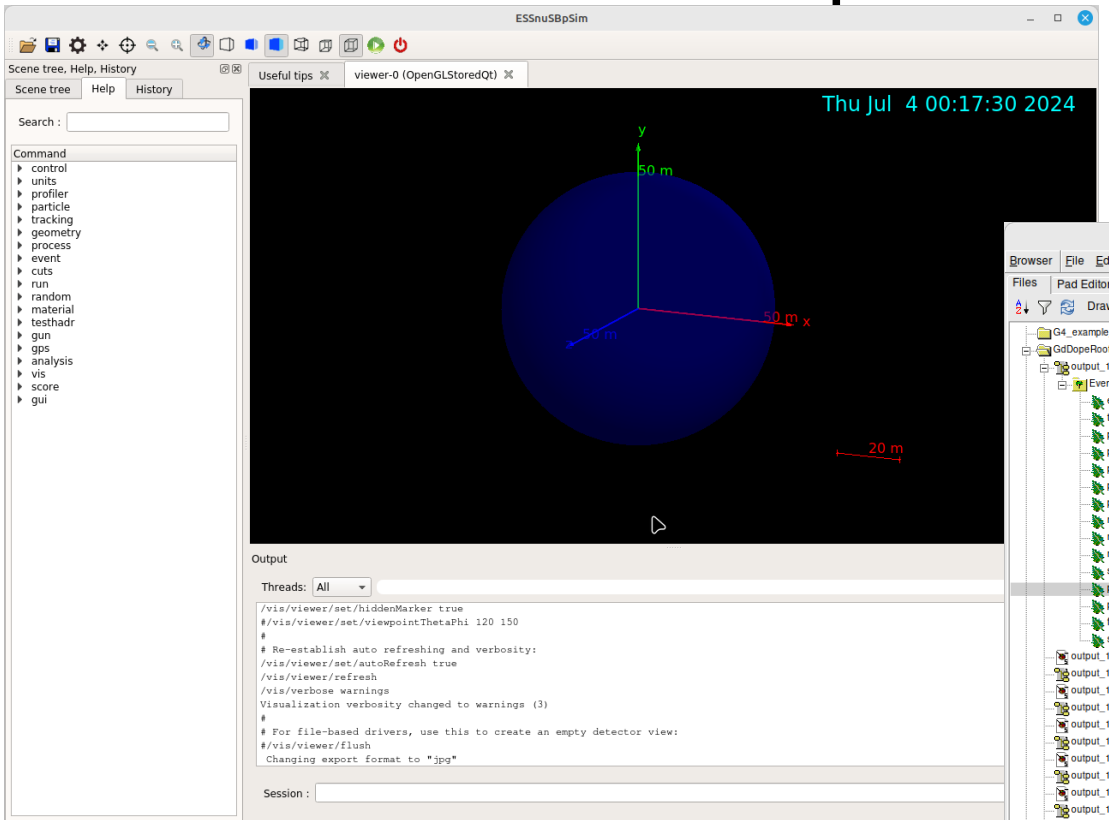
co-funded by

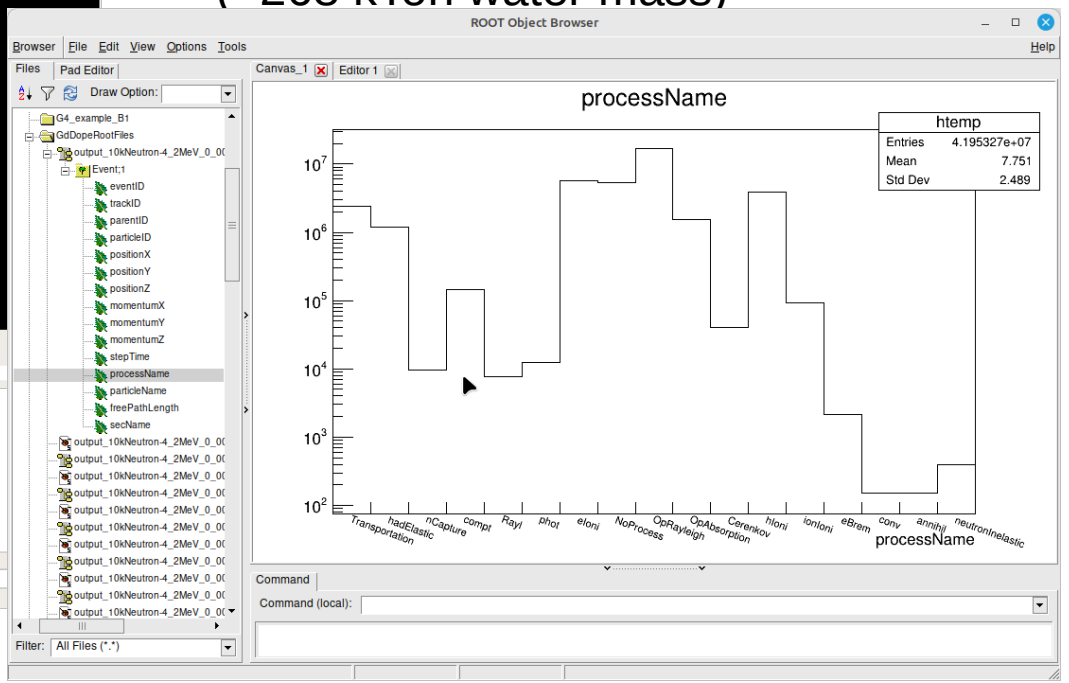
Geant4 Simulation on Gd doping in water

ESSnuSBplus 2nd Annual Meeting
September 25th 2024

A Brief Description of Simulation Package

As a strating point we use a simple water volume
With a radius of 40m
(~268 kTon water mass)





Geant4 Simulation on Gd Doping in Water

Version of Record: https://www.sciencedirect.com/science/article/pii/S0168900221010883
Manuscript_ee15101add5d2e955695972c9e94b70c

First Gadolinium Loading to Super-Kamiokande

K. Abe[a,at], C. Bronner[a], Y. Hayato[a,at], K. Hiraide[a], M. Ikeda[a,at], S. Imaizumi[a], J. Kameda[a,at], Y. Kanemura[a], Y. Kataoka[a], S. Miki[a], M. Miura[a,at], S. Moriyama[a,at], Y. Nagao[a], M. Nakahata[a,at], S. Nakayama[a,at], T. Okada[a], K. Okamoto[a], A. Orii[a], G. Pronost[a], H. Sekiya[a,at], M. Shiozawa[a,at], Y. Sonoda[a], Y. Suzuki[a], A. Takeda[a,at], Y. Takemoto[a], A. Takenaka[a], H. Tanaka[a], S. Watanabe[a], T. Yano[a], S. Han[b], T. Kajita[b,at], K. Okumura[b,at], T. Tashiro[b], J. Xia[b], G. D. Megias[c], D. Bravo-Berguño[d], L. Labarga[d], Ll. Marti[d], B. Zaldivar[d], B. W. Pointon[e,ax], F. d. M. Blaszczyk[g], E. Kearns[g,at], J. L. Raaf[g], J. L. Stone[g,at], L. Wan[g], T. Wester[g], J. Bian[h], N. J. Griskevich[h], W. R. Kropp[1h], S. Locke[h], S. Mine[h], M. B. Smy[h,at], H. W. Sobel[h,at], V. Takhistov[h,at], J. Hill[i], J. Y. Kim[j], I. T. Lim[j], R. G. Park[j], B. Bodur[k],

https://doi.org/10.1016/j.nima.2021.166248

Gd	Gd2(SO4)3
0.0001	0.0002
0.001	0.0019
0.003	0.0058
0.005	0.0096
0.008	0.0153
0.009	0.0173
0.01	0.0192
0.011	0.0211
0.012	0.0230
0.02	0.0384
0.03	0.0575
0.04	0.0767
0.05	0.0959
0.08	0.1534
0.1	0.1918
0.15	0.2876
0.2	0.3835
0.5	0.9588
0.8	1.5340
1	1.9175

Simulation Details

Neutron events using water doped with different Gd Concentration(20 scenarios)

- Initial kinetic energy is 4.2 MeV
- Initial starting point is (0,0,0)
- Initial direction is (0,0,1)
- 10k events each

Gd	Gd2(SO4)3
0.0001	0.0002
0.001	0.0019
0.003	0.0058
0.005	0.0096
0.008	0.0153
0.009	0.0173
0.01	0.0192
0.011	0.0211
0.012	0.0230
0.02	0.0384
0.03	0.0575
0.04	0.0767
0.05	0.0959
0.08	0.1534
0.1	0.1918
0.15	0.2876
0.2	0.3835
0.5	0.9588
0.8	1.5340
1	1.9175

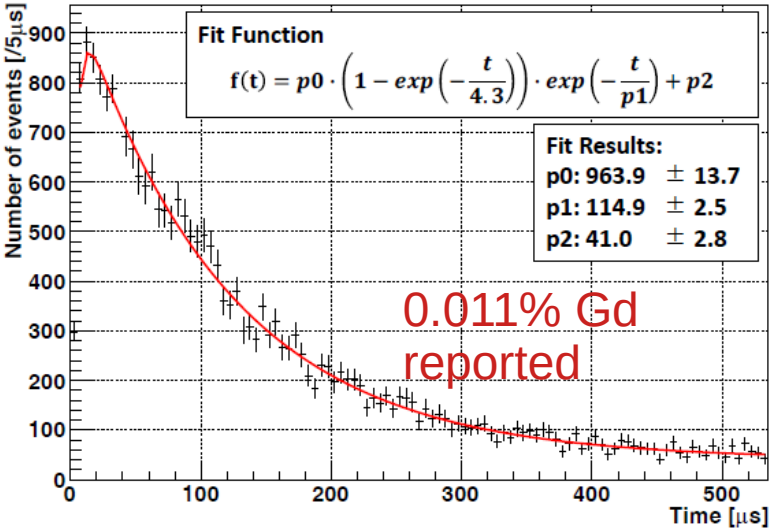
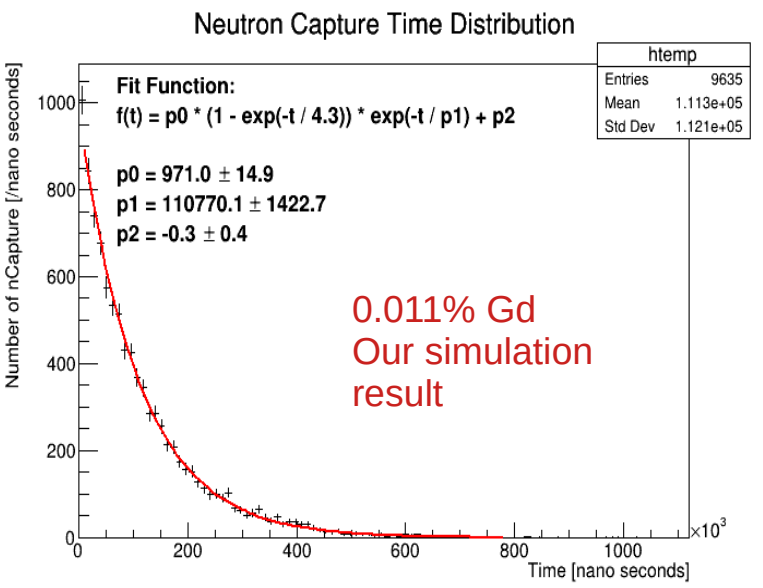
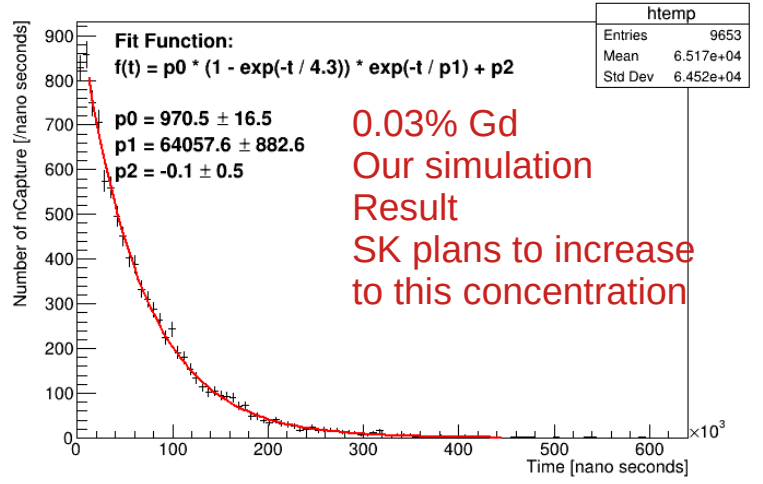


Figure 12: An example of the time distribution of neutron capture event candidates (black data points) and its fit function (red line), measured with the Am/Be source at the Z=0 m position on September 29, 2020. Each such measurement contained about 30 minutes of data with the Am/Be source deployed at various locations in the SK detector. Time zero is defined by the detection of the prompt 4.4 MeV gamma-ray BGO scintillation event. The neutron capture time constant is represented by $p1$, while the thermalization time constant of 4.3 μs is derived from summed analysis of these measurements.

p0: Bin content
p1: neutron capture time constant
p2: background

4.3 micro second is the thermalization time constant which is also derived by the experiment





https://doi.org/10.1016/j.nima.2021.166248

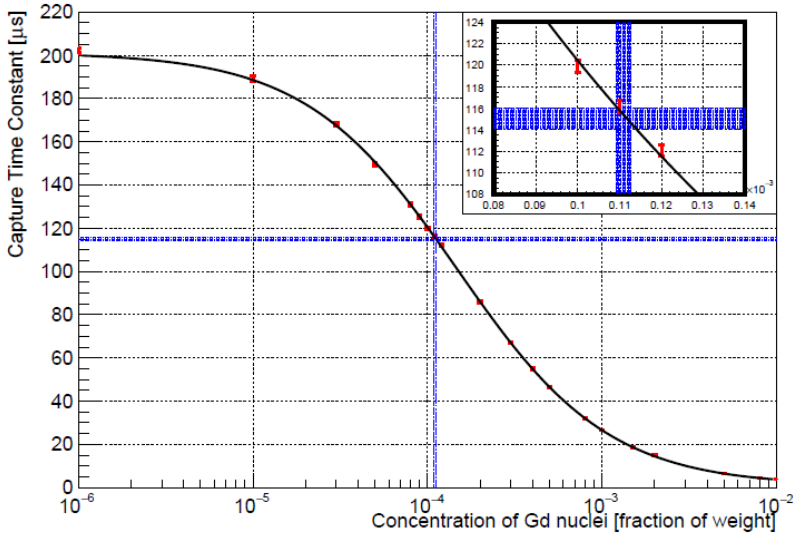
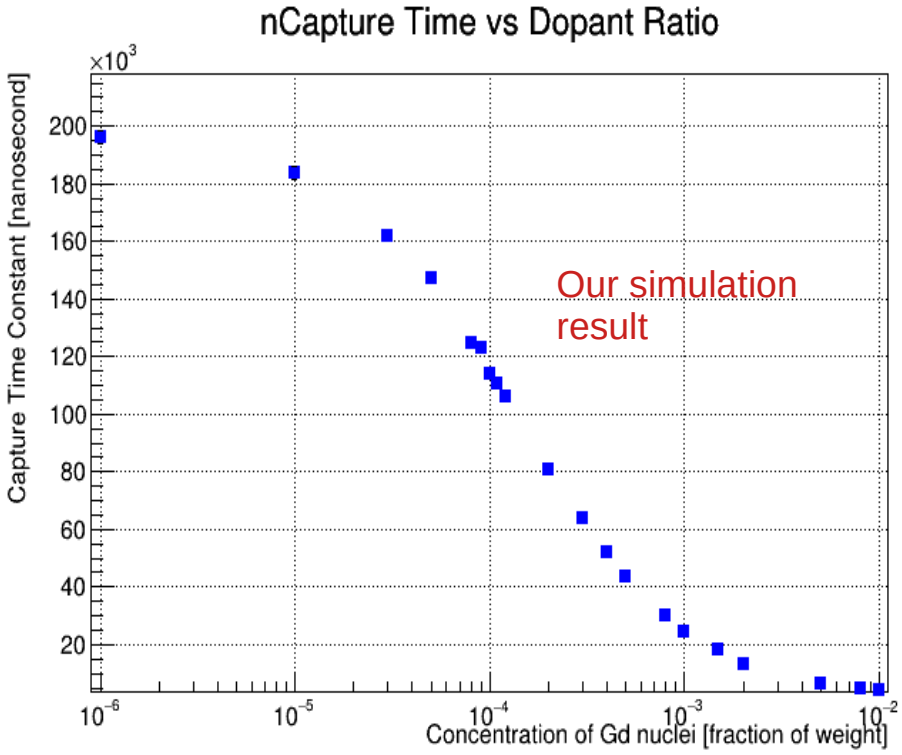


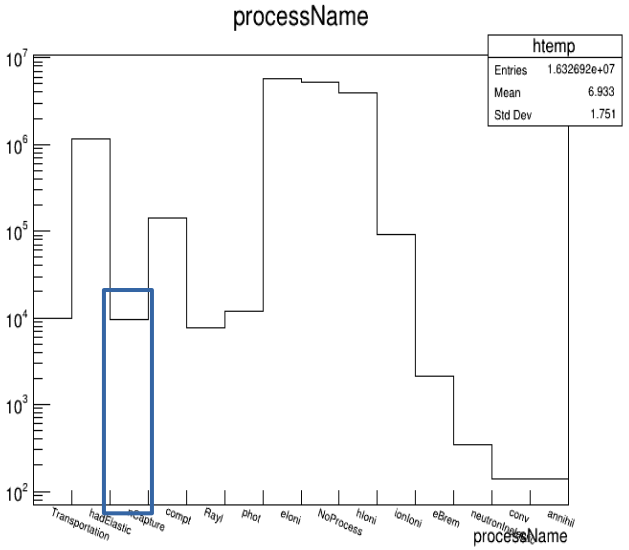
Figure 13: Neutron capture time constant as a function of the gadolinium concentration. The red points correspond to the Geant4 Monte Carlo simulation, while the black line corresponds to an approximate polynomial function. The horizontal blue band represents the mean neutron capture time constant measured with the Am/Be source, and the vertical blue band represents the derived concentration, which is consistent with the estimation from the weight (110 ppm) described in Section 4.3.



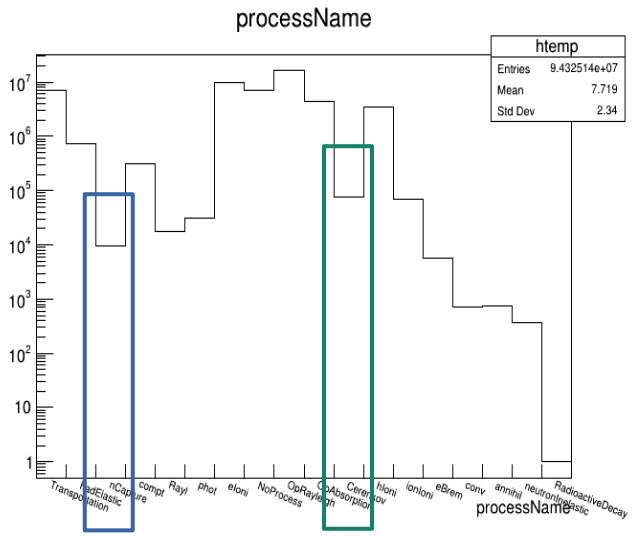
https://doi.org/10.1016/j.nima.2021.166248

Comparison of Gd concentration on number of Cerenkov process (based on our sim. results)

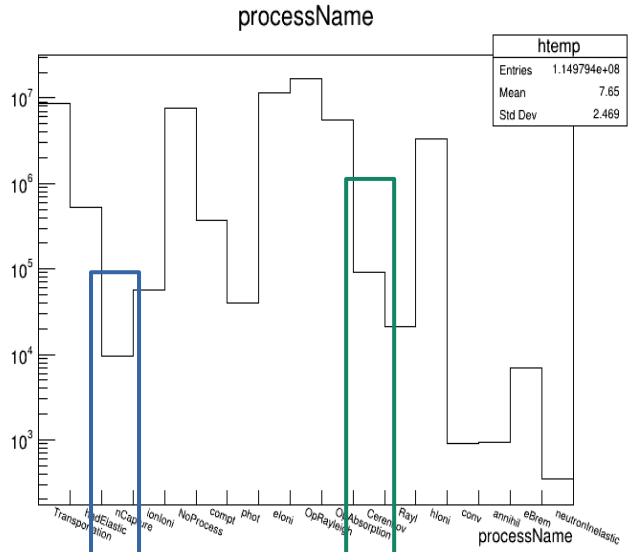
Neutron Capture Process, Cerenkov Process



Un doped water
Our simulation
Result



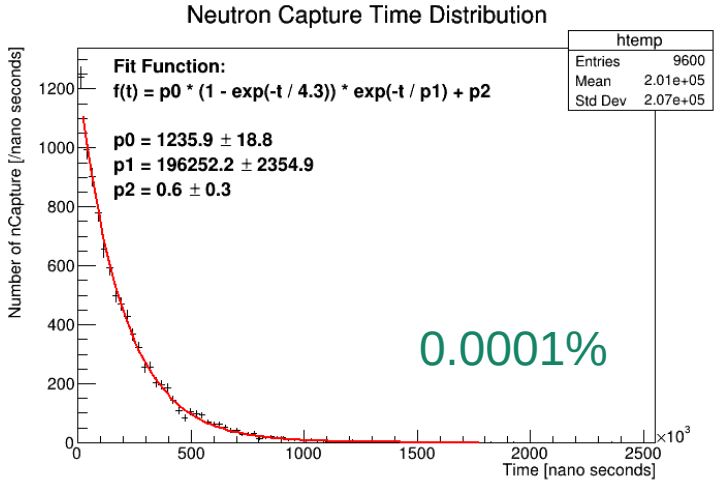
0.011% Gd-doped water
Our simulation
Result

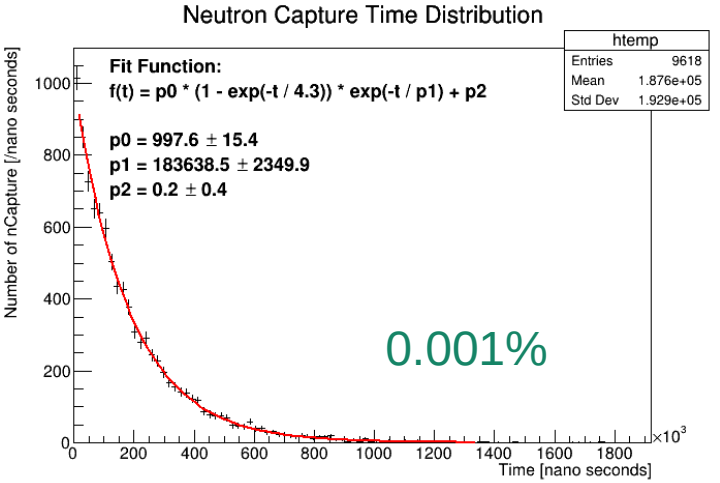


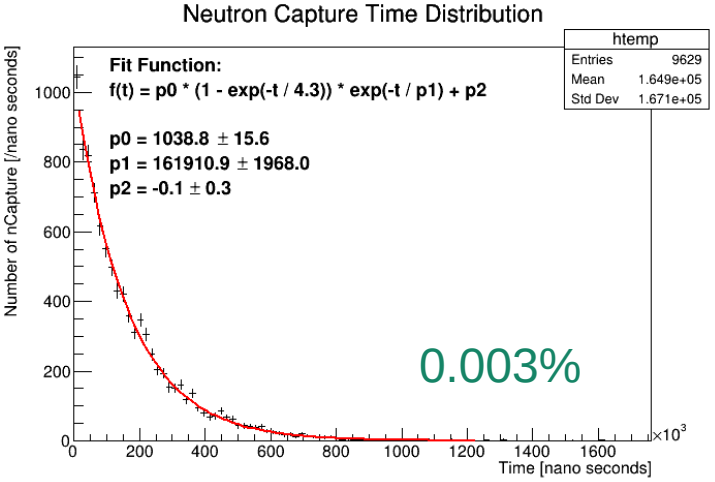
0.03% Gd-doped water
Our simulation
Result

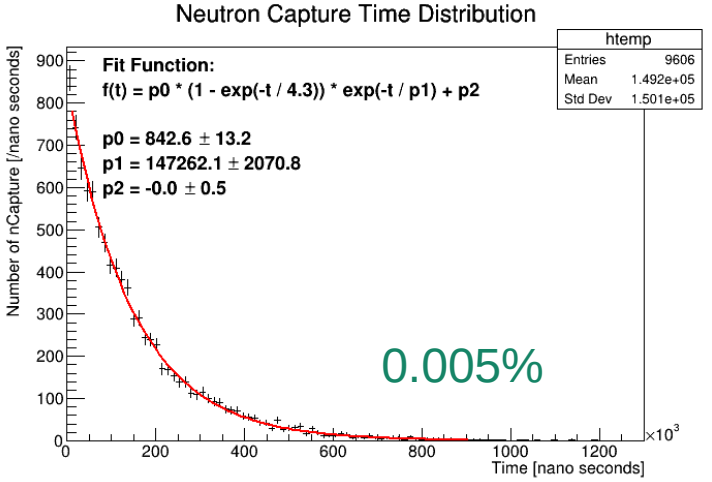
Back up slides

Individual fits I



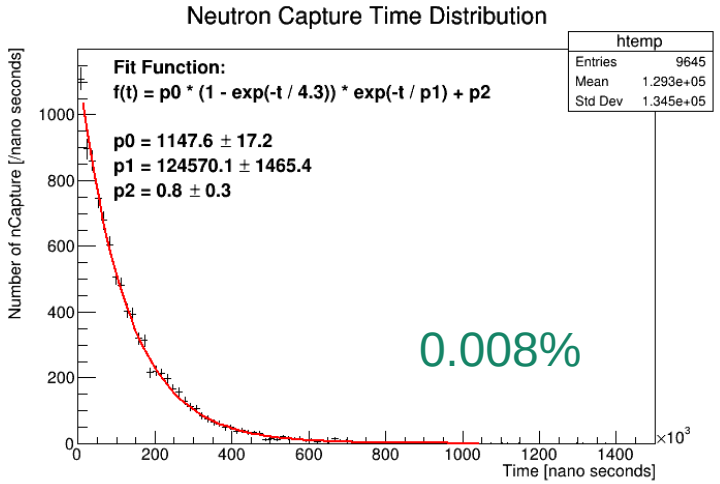


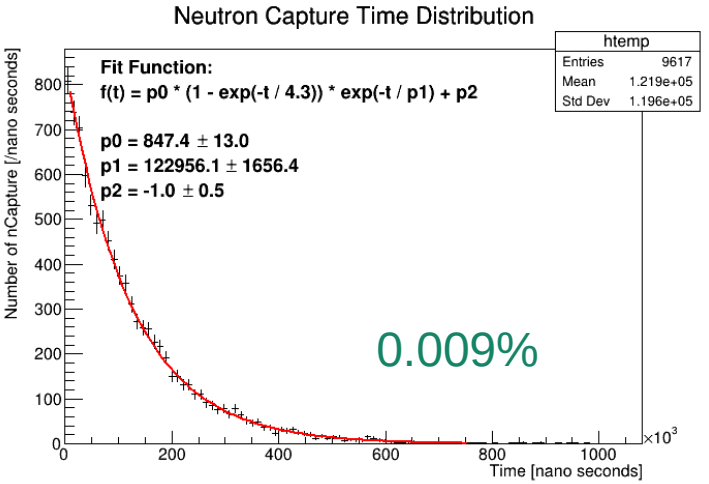


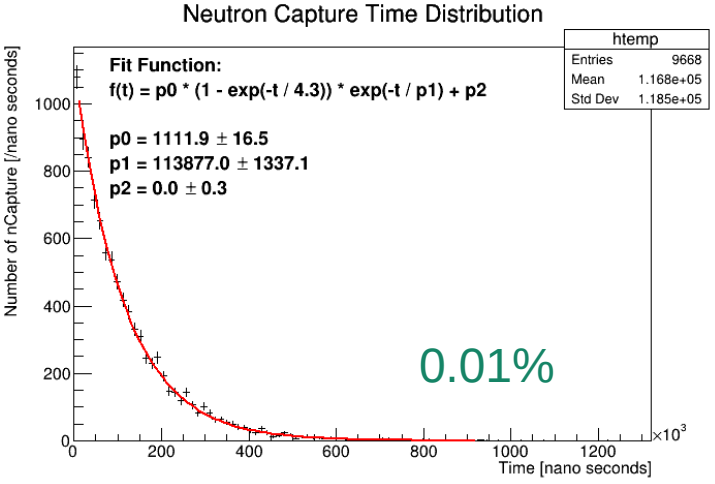


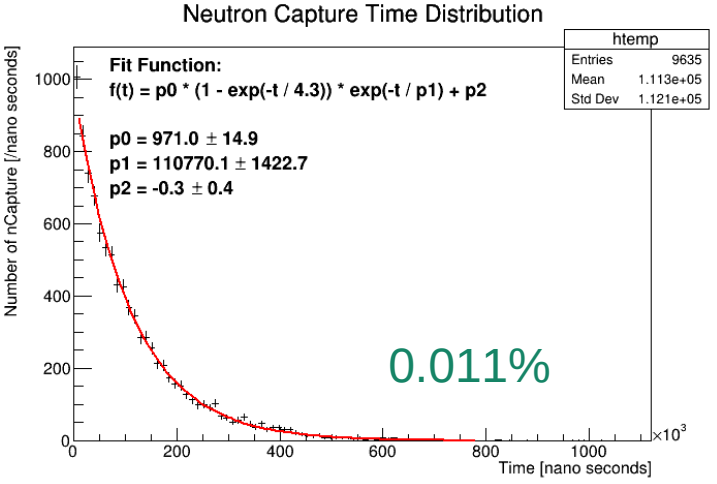
x% Gd nuclei

Individual fits II



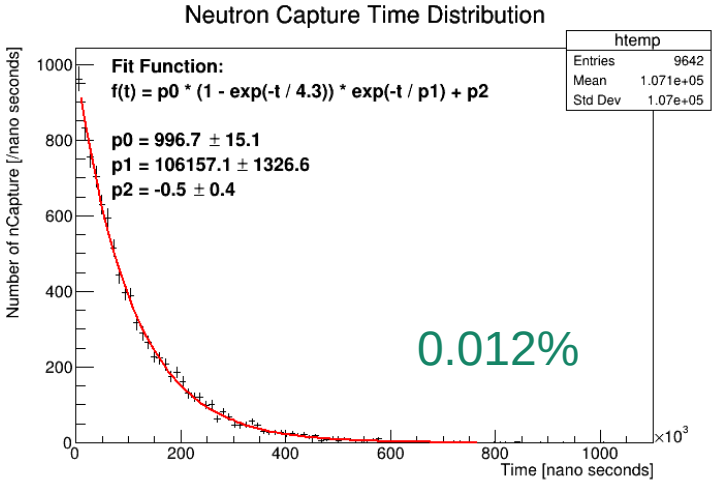


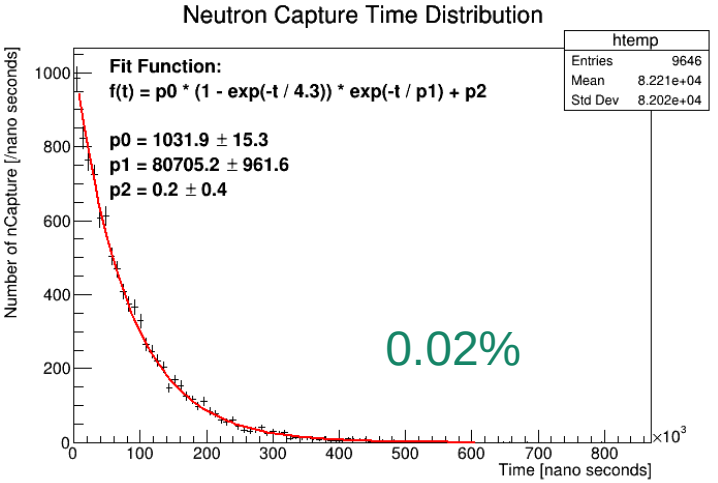


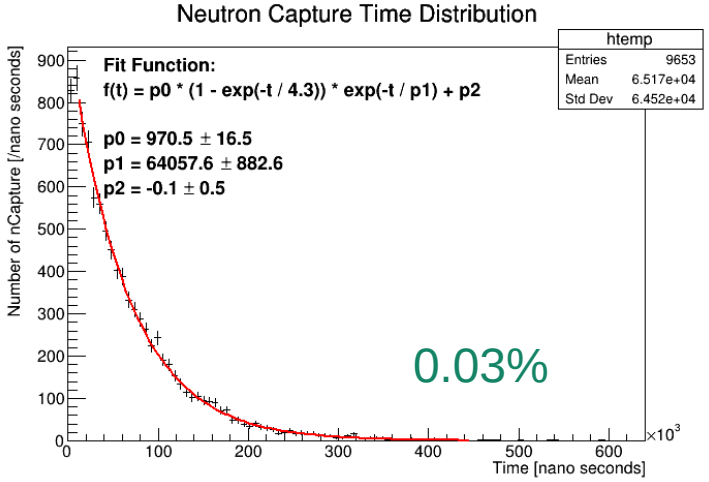


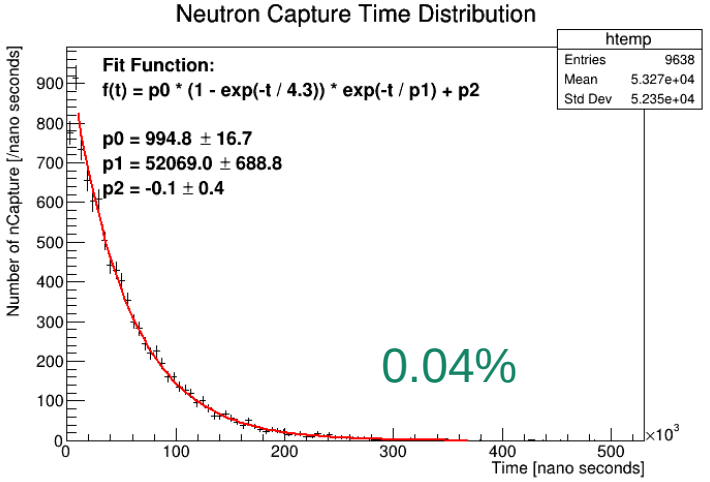
x% Gd nuclei

Individual fits III



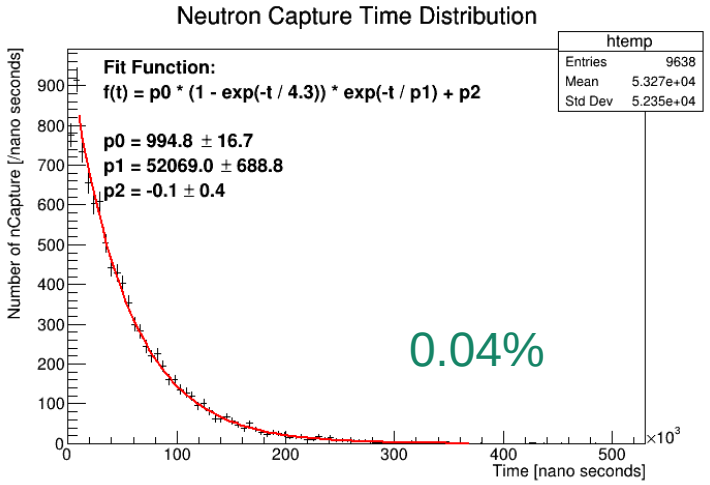


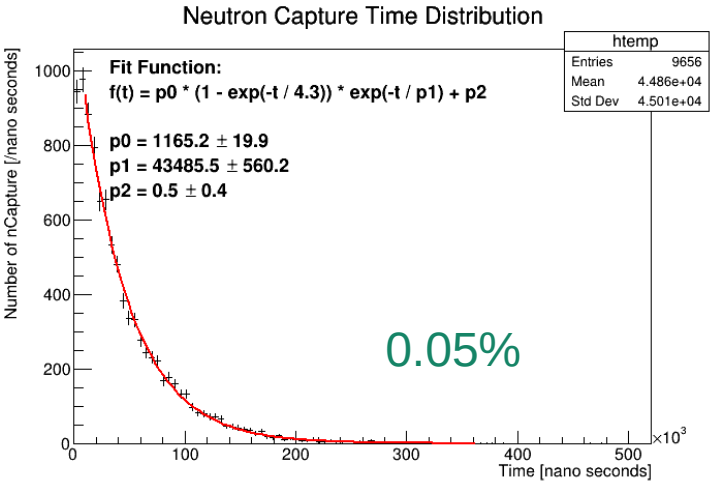


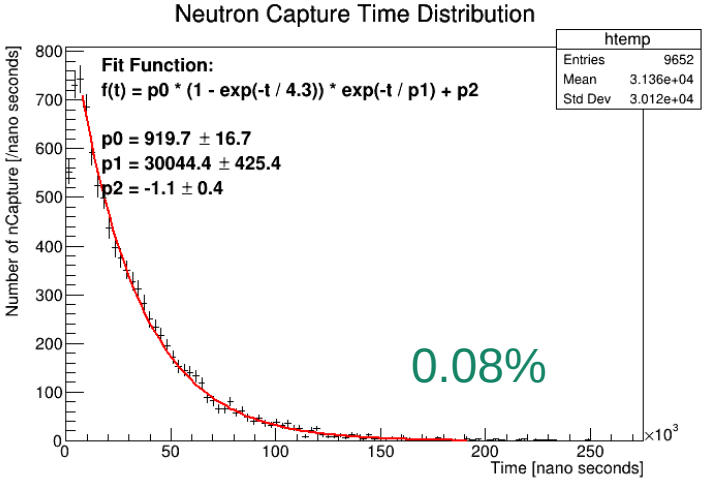


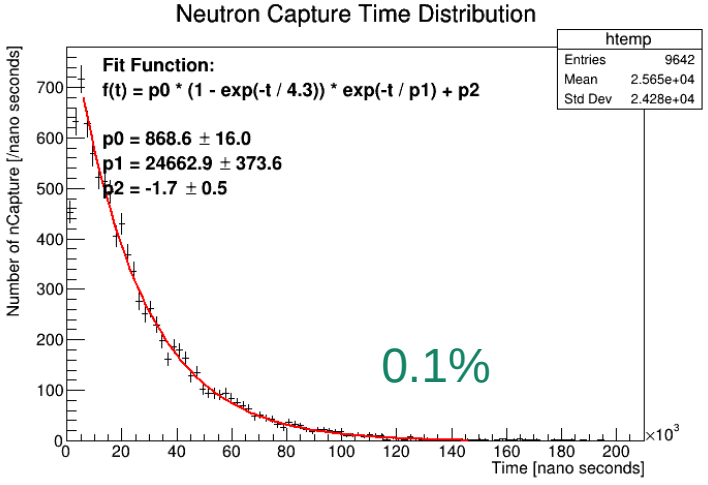
x% Gd nuclei

Individual fits IV



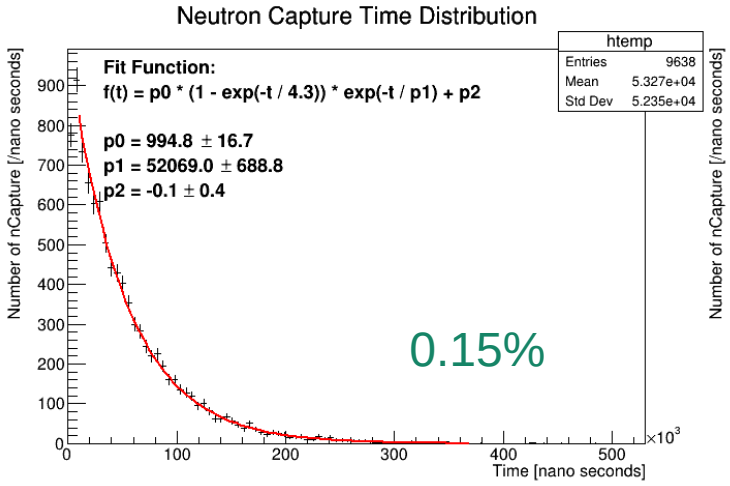


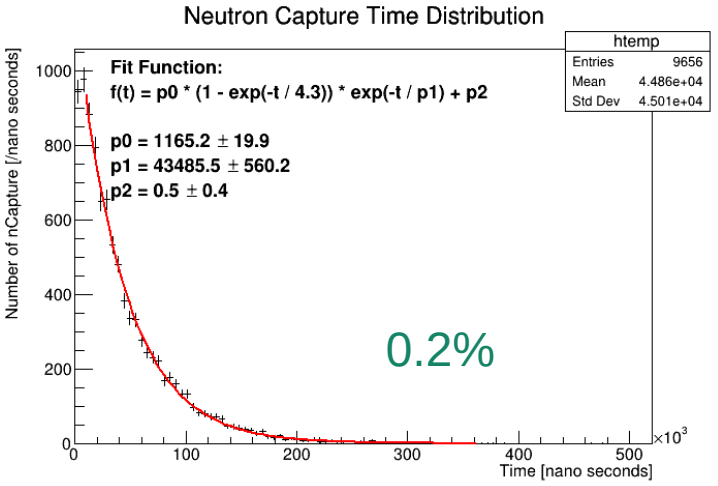




x% Gd nuclei

Individual fits V





x% Gd nuclei